BASIC MEDICAL SCIENCES FOR TECHNICIANS

PHYSIOLOGY

MEDICAL LABORATORY TECHNIQUES FOR ROUTINE DIAGNOSTIC TESTS

Vol. II

G. GURU
Project Coordinator

राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
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FOREWORD

The programme of vocationalization of higher secondary education has been accepted by the country as it holds forth great promise for linking education with the productivity and economic development of the country by providing education for better employability of the youth.

In view of the importance of the programme the NCERT is making an all out effort to provide academic support to the implementing agencies in the States. One of the major contributions of NCERT is in the field of curriculum development and in the development of model instructional materials. The materials are developed through workshops in which experts, subject specialists, employers' representatives, curriculum framers and teachers of the vocational course are involved.

The present volume on **Physiology** is one of the series on "Medical Laboratory Techniques for routine diagnostic tests" and is meant for the students of Medical Laboratory Technician course. It is being published for wider dissemination amongst students and teachers throughout the country. I hope that they will find the volume useful.

I am grateful to those who have contributed to the development of this volume. I must acknowledge also the immense interest taken by Prof. A.K. Mishra, Head, Department of Vocationalization of Education in inspiring his colleagues in their endeavours to develop instructional materials. Shri G. Guru, Reader, functioned as the Project Coordinator for the development of this title. He has my appreciation and thanks for planning, designing and conducting the workshop, for technical editing and for seeing this title through the press.

Suggestions for improvement of this volume will be welcome.

P.L. MALHOTRA
Director
National Council of Educational
Research & Training.

New Delhi,
March, 1986

PREFACE

Ever since the introduction of vocationalization in our school system by several States and Union Territories in our country the paucity of appropriate instructional materials has been felt as one of the major constraints in implementation of the programme and a source of great hardship to pupils opting for vocational studies at the higher secondary stage.

The Department of Vocationalization of Education of the National Council of Educational Research & Training, New Delhi has started a modest programme of developing instructional materials of diverse types to fill up this void in all major areas of vocational education. The task is too gignatic to be completed by any single agency but the model materials being developed by us might provide guidance and impetus to the authors and agencies desiring to contribute in this area. These are based on the national guidelines developed by a working group of experts constituted by NCERT.

The present volume is on **Physiology** and is meant for the pupils and the teachers of Medical Laboratory Technician vocation being offered in a number of States and Union Territories. It contains basic medical science in Physiology required for a Laboratory technician. It is hoped that the users will find it immensely useful.

The material was developed during the workshop held in Dr. T.M.A. Pai Research Centre, Manipal. The present version was finalised after incorporating suggestions and comments by experts. The names of the contributors/reviewers are mentioned elsewhere and their contributions are admirably acknowledged. Shri G. Guru, Reader and Coordinator of this Project, Department of Vocationalization of Education, deserves special thanks for bringing the manual in the present from. The assistance of all in the Dr. T.M.A. Research Centre Manipal, especially of Dr. A. Krishna Rao,

Dean, Kasturba Medical College, Manipal and that of the Department of Vocationalization of Education, are also thankfully acknowledged.

ARUN K. MISHRA
Professor & Head
Department of Vocationalizaiton of Education

New Delhi,
March, 1986.

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The Participation of the following experts in the development as contributor of the present title reviewers is gratefully acknowledged.

Contributor

Miss N. Nagaraja Kumari

Reviewers

Dr. A. Krishna Rao

Dr. P. Laxminarayan Rao

Dr. R.D. Srivastava

GANDHIJI'S TALISMAN

"I will give you a talisman. Whenever you are in doubt or when the self becomes too much with you, apply the following test :

Recall the face of the poorest and the weakest man whom you may have seen and ask yourself if the step you contemplate is going to be of any use to him. Will he gain anything by it ? Will it restore him to a control over his own life and destiny ? In other words, will it lead to Swaraj for the hungry and spiritually starving millions ?

Then you will find your doubts and your self melting away."

M.K. Gandhi

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1. Defination of Physiology and its Scope for Medical Laboratory Technician (MLT)

Physiology is the study of the functions of normal human body as a whole and of the individual structures and organs contained in human body.

A student of MLT should acquaint himself/herself with the basic knowledge of Physiology. It is very important to know the functions of various systems in the body.

MLT tests for either the function of different organs or the constituents in different fuilds. For example when MLT examines urine sample he/she is testing whether any abnormal substance is present in the urine. So an MLT must know normally what substances are present, so that he/she can make out any abnormal substances present. MLT has to learn the normal functions of different fluids of the body.

An MLT should know about the structure & functions of different blood cells. He or she should know as to how one digests, assimilates, breathes, excretes, reproduces etc. Another important and interesting function of the body is overall control of different organs so that the bodily functions go on smoothly. The controlling systems are endocrine glands and nervous system.

The endocrine glands control different organs to maintain the constituents of the body fluid constant. And it also help in the growth and development of our body. The nervous system controls and coordinates all the systems of the body and gives us the awareness of external environment. It is concerned with the learning, behaviour etc. and guides us at every moment. Then all these functions of various systems co-operate and coordinate to give us balanced body functions, which is called as homeostasis. Anatomy, Physiology Bio-physics, Bio-chemistry are basic sciences in understanding bod mechanisms.

2. Introduction to Systems in Human Body and Their Physiological Functions

The human body consists of many organs, each organ having its own particular function to perform. Each organ is made up predominantly of a particular type of tissue. The cell is the unit of the tissue. The cells are adapted to perform the special functions of the organ. The organs are organised into several systems according to the functions they perform. They are outlined below.

Blood & Lymph are fluid tissues. Blood is the main transport system. It carries oxygen (O_2) and nutritive substances and antibodies to the tissue and removes carbondioxide (Co_2) & waste-products from the tissues. The physical properties of water in the blood helps to maintain body temperature. Blood carries metals like iron and hormones like thyroxine.

Circulatory system: Heart is the chief organ of circulation of the blood. The blood is pumped by the heart along the arteries to the capillaries and is returned by veins.

Respiratory system consists of passages and organs concerned with breathing. O_2 from the air is taken into the lungs and O_2 from that diffuses into the blood which carries it to the tissues. The Co_2 which is produced by the tissues is carried by the blood from the body tissue to the lungs and breathed out in the expired air.

Digestive system consists of alimentary canal and the glands associated with it. It deals with the digestion and absorption of food. The food supplies energy to the body and supplies substances for its growth and maintenance.

Urinary system consists of kidneys, ureters and urinary bladder. The kidney helps to keep the composition of the blood constant by excretion of waste products.

Skin protects the body, and it is concerned with general sensation and it plays an important role in regulation of body temperature.

Endocrine glands or ductless glands: These glands produce special chemical substances which are called as hormones which pass

directly into the blood stream. These hormones control the bodily functions.

Reproductive system is concerned with the preservation of species. The function of male reproductive organ is to produce sperms and male sex hormone. The function of female reproductive organ is to produce ova and female sex hormones.

Special sense organs include tongue (taste), nose (smell), eye (sight) and ear (hearing). Through these organs the persons are aware of external environment.

Nervous system consists of brain, spinal cord and the nerves arising from them. They are concerned with the quick control of bodily function & co-ordination.

Locomotor system: This includes the parts concerned with the movements of the body. This comprises bones, joints and muscles, fescia and tendons.

3. Blood

Blood is a fluid tissue. It circulates in the vascular system.

3.1. General Functions of Blood

1) Nutritive: It receives digested food materials such as glucose, amino acids, fatty acids, vitamins and water and supplies them to the different tissue cells.

2) Excretory: Blood transports the waste products of tissue metabolism, eg, urea, uric acid, createnine & other substance to the kidney for elimination.

3) Respiratory: Blood transports O_2 from the lung to the tissues and CO_2 from the tissues to the lungs. O_2 is used by the tissues for the oxidation of food and production of energy. CO_2 is expelled through the lungs.

4) Regulation of body temperature.

5) Hormone transport: Hormones of pituitory, thyroid and adernal glands etc. are transported by the blood to the tissues.

6) Defence mechanism: Blood transports leucocytes, antibodies or immune bodies and protect the body against bacteria and other injurious agents.

7) Water balance: It maintains water content of the tissues.

8) Acid-base balance: The plasma proteins and haemoglobin help in the regulation of acid base balance.

9) Clotting of Blood: The plasma and platelets are important for the clotting of blood.

10) Maintenance of colloidal osmotic pressure: The plasma protein albumin exerts 80% of colloidal osmotic pressure. The normal colloidal osmotic pressure is 25 mm Hg. This pressure is essential to retain the fluid in the vascular compartment.

11) Viscosity: Plasma proteins are responsible for maintaining viscosity of the blood which helps in maintaining Blood pressure.

3.2. Physical Properties of Blood

Opaque fluid: Scarlet red in colour when taken from artery, and purple red when taken from vein. Normal specific gravity of whole blood for men is 1050-1061 and the values for women are little lower.

Viscosity: The blood is 5 times more viscous than water

Osmatic pressure: a) Colloidal osmotic pressure 25 mm Hg.
b) Crystalloid osmotic pressure 5.6 atmospheres

pH : 7.4± 0.04

3.3. Composition of Blood

Blood is a complex fluid with cells suspended in it. It consists of 45% of cells and 55% of fluid part known as plasma.

Cells: Red Blood cells (RBC) Erythrocytes
White Blood cells (WBC) Leucocytes
Platelets (Thrombocytes)

Plasma: Liquid with dissolved substances
Water = 90 — 92%
Solids = 8 — 10%

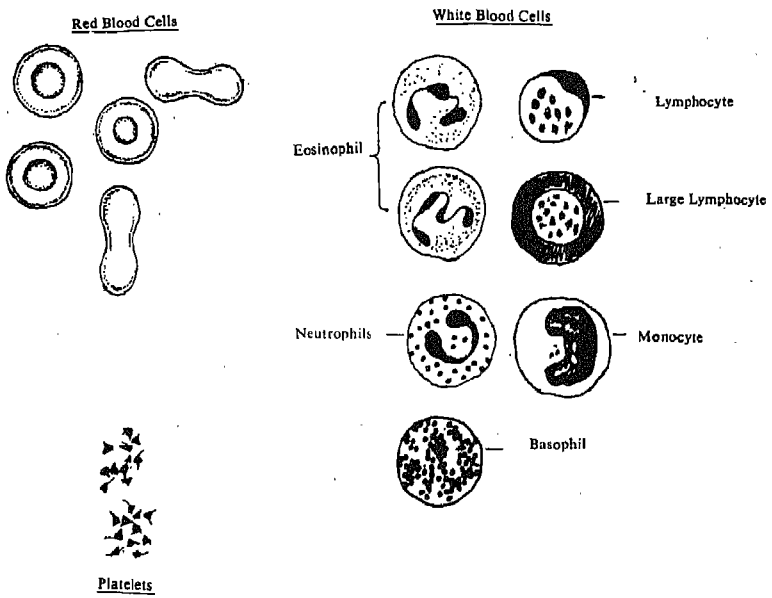


Fig II. 2.1 'BLOOD CELLS

3.4. Plasma

Plasma contains organic and inorganic substances.

1) The organic substances:

a) Proteins—serum albumin, globulin, fibrinogen, prothrombin etc.

b) NPN—Non Protein Nitrogenous substances are urea, uric acid, creatine, creatinine, xanthine, hypoxanthine, amino acids and NH_3.

c) Carbohydrates — glucose.

d) Fats — neutral fats, cholesterol, phospholipids.

e) Various substances—hormones, antibodies, enzymes, bilirubin, carotene.

2) Inorganic substances:

Salts of Na, K, Ca, P, Mg etc.

3.5. Blood Cells

3.5.1. Red Blood cells: It is disc shaped biconcave, non-nucleated cell. It is 6-9μ in diameter and 2μ in thickness; average size

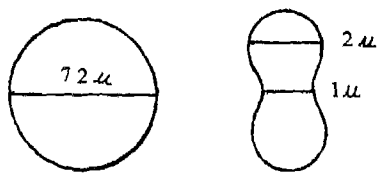


Fig. 11.2.2 RED BLOOD CELLS

is 7.2μ. The normal cell count in adult male is 50,00000/c,mm, in adult female 4.5 millions/c.mm, in infants 6.7 millions/cmm.

R.B.C. contains haemoglobin, stroma protein, lipids, organic and inorganic substances.

R.B.C. count increases in the following conditions: (1) Evening (2) High temperature (3) After exercice (4) High altitudes (5) Injection of adrenaline (6) Excitement (7) Polycythemia vera (8) Cardio pulmonary diseases.

The RBC decreases in cases of anaemias.

RBC Development: In foetal life RBCs are produced mainly in the spleen and liver. After birth from all the bones. Slowly most of the long bones stop RBC production except the upper ends of humerous and femur, flat bones, vertebra, skull, sternum, pelvis etc.

RBC development involves two processes: multiplication & maturation.

Factors essential for RBC formation:

a. Hypoxia.
b. Food: First class proteins like milk, eggs, meat, pulse etc.
c. Vit B_{12}: Liver, bone marrow, meat, milk, pulses are sources of vit B_{12}; it is required for maturation of cells. Leafy vegetables and Yeast give folic acid. Citrate fruits like orange and lemon are good sources of vitamin C.
d. Metals: Iron for Hb formation.
e. Erythropoitin, a hormone, produced from the kidney which helps in multiplication of cells.
f. Intrinsic factor produced from the gastric mucosa which helps in the absorption of vit B_{12}.

Life span of RBC: RBC survives in the circulation for 120 days. After this the old RBCs are destroyed in reticuloendothelial cells. The pigment haem undergoes several chemical changes giving rise to bilirubin. Normal concentration of serum bilirubin is 0.2 to 0.8 mg/100 ml. When it exceeds 2 mg/100 ml, the skin, sclera, nail beds get yellowish tinge. This yellowish discolouration due to excess of bilirubin is called jaundice. There are 3 types of jaundice: 1. Prehepatic or haemolytic jaundice. 2. Hepatic jaundice. 3. Post hepatic or obstructive jaundice.

Haemoglobin: It is a complex protein rich in iron. Iron part combines with O_2 forming oxyhaemoglobin. The globin part combines with CO_2 forming carbamino compound. The amount of Hb present in normal blood is about 15 g/100 ml blood. 1 g. of Hb when it is fully saturated carries 1.34 ml of O_2. Besides transporting O_2 and CO_2 haemoglobin regulates excessive changes in acid base balance of the blood.

Decrease in haemoglobin concentration below 8 g/100 ml is called as anaemia.

There are four types of anaemias:

1. Iron deficiency anaemia;
2. Anaemia due to lack of Vit. B_{12};
3. Haemolytic anaemia in which the RBCs are broken down rapidly;
4. Aplastic anaemia is the failure of bone marrow to produce the RBCs.

Blood groups: There are 2 main systems of Blood groups: 1.

ABO system; 2. Rh system.

The RBCs contain group specific substances known as agglutinogens and the plasma or serum contains agglutinins. The human beings are divided into 4 groups on the basis of presence or absence of A group, B group, AB group and O group.

The group specific substances present in these groups are given in the tabular column below:

Blood group	agglutinogens in RBC	agglutinins in plasma	% of persons
A	A	B or anti B	42
B	B	A or anti A	9
AB	A & B	Neither	3
O	Neither A nor B	Both anti A & anti B are present	45

Rh system is of 2 types. The persons who possess Rh agglutinogens on their RBC are called Rh +ve persons. Those who do not have Rh agglutinogens are called as Rh -ve persons.

Importance of Blood group:

1. Blood transfusion
2. Medico legal cases

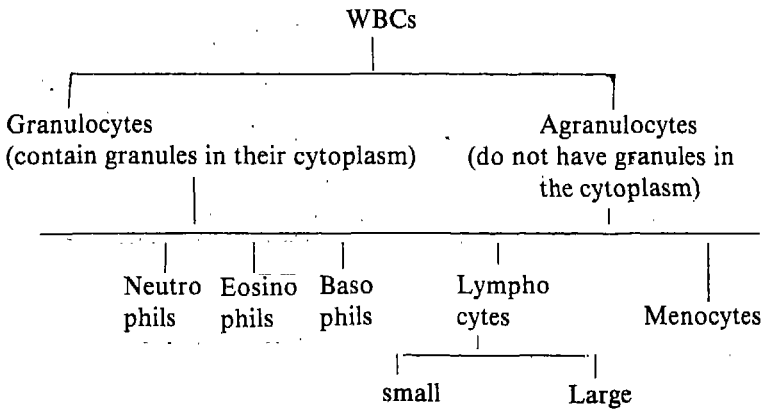
3.5.2. White Blood Cells: WBCs are colourless, larger, nucleated cells and fewer in number. The total WBC count in an adult is 4000 to 11,000/cmm of blood. If the count is more than 11,000/cmm it is called as leucocytosis which occurs in pyogenic infections and inflammatory conditions.

Decrease in count is known as leucopenia which occurs in typhoid and other conditions.

Functions of WBC: Mainly defence mechanism. They protect the body from micro-organisms. The granulocytes and monocytes are concerned with phagocytosis (i.e. they eat the bacteria). Lymphocytes are concerned with anti-body formation. Eosinophils are anti allergic and basophils liberate heparin which is an anti coagulant.

Classification of WBC: They are classified into 2 main groups depending upon the presence or absence of granules in the cyto-

Classification and morphology of WBCs.



Size of the cell	*10-14μ*	*10-14μ*	*8-12μ*	*8μ*	*10-14μ*	*14-18μ*
Nucleus	2-5 lobed	2 lobed	Single	Single big shaped	Single kidney or round	Horse shoe shaped nucleus eccentrically placed
Cytoplasm	Purple fine numerous granules	Reddish pink big granules	Bluish big very few granules	Sky blue coloured small amount of cytoplasm	Sky blue coloured large quantity of cytoplasm	Muddy grey coloured cytoplasm.
%	50-70%	1-4%	0-1%	20-30%		2-8%

plasm; further division of granulocytes depends upon the colour of the granules present in the cytoplasm. Neutrophils have fine granules stained with both acidic and basic dye.

Eosinophils have coarse granules which are reddish pink in colour, stained by acidic dye.

Eosinophils have coarse granules which are reddich pink in colour, stained by acidic dye.

Basophils contain big blue granules which are stained by basic dye.

3.5.3. Platelets: Platelets are tiny blood cells with 2.5 μ in size. They are small non-nucleated refractile bodies.

The normal count is 2.5 lakh to 5 lakh/cm of blood. Decrease in platelet count is known as thrombocytopenia.

Function of Platelets:

1. Coagulation.
2. Hemostasis—to arrest the bleeding by vasoconstriction and by platelet plug formation.
3. It liberates 5 HT or serotonin which brings about vasoconstriction.
4. They help in clot retraction.

3.6. Coagulation of Blood

When blood is shed, it quickly becomes red jelly. Within few minutes this jelly or clot contracts and oozes a straw coloured fluid known as serum. This fluid does not contain fibrinogen and other clotting factors. Clotting of blood is a complicated process. Several plasma factors and platelets are involved in the reaction.

Steps of clotting of blood:

1. Formation of thromboplastin: There are 2 ways by which it is formed:
   a. Intrinsic thromboplastin which needs platelets and plasma factors.
   b. Extrinsic thromboplastin which requires tissue factors formed due to tissue injury and certain plasma factors.
2. Conversion of prothrombin to enzyme thrombin.
3. Conversion of soluble fibrinogen to insoluble fibrin in the presence of the enzyme thrombin.
4. The fibrin threads with entangled blood cells is called clot. Calcium in ionic form is essential in each step. Without calcium ions coagulation can not take place.

Anti Coagulants: These are the substances which prevent coagulation.

Eg. 1. Na citrate	removes ionic calcium from the blood.
2. Ammonium-potassium oxalate	— do —
3. EDTA	— do —
4. Heparin	prevents formation of thromboplastin. It is anti-thrombin.

5. Dicoumerol	acts inside the body and prevents the formation of prothrombin.

Vitamin K: Vitamin K is necessary for the production of some coagulation factors. In the absence of Vit. K the amount of coagulation factors present in the blood is less; so the blood coagulation time increases.

3.7. Blood Volume

It is the total volume of blood in the circulatory system. Normal blood volume in a man with 70 kg. of weight is 5 litres. Maintenance of blood volume is important to maintain normal blood pressure.

Factors which regulate blood volume.:

1. Blood pressure, diffusion, osmosis and capillary permeability.
2. Vitamins to control capillary permeability.
3. Hormones—anti diuretic hormone facilitates water reabsorption in the kidney tubules and aldosterone balances the Na and K ion.
4. Paratharmone controls calcium level in the blood and controls the capillary permeability.
5. Thirst and sweat are natural forces affecting blood volume.

3.8. Lymph

Lymphatic system is connected with the circulatory system. Lymphatic system consists of lymph node & lymph vessels. The lymph nodes are present in certain important parts of the body to filter the bacteria. They also produce lymphocytes. These lymph nodes are present in the neck, axilla, thorax, abdomen and groin. Lymph flows in lymphatic vessels. Formation of the fluid & lymph is shown in Fig. 11.2.3.

Composition of Lymph: Lymph is similar to the plasma but contains less proteins; it contains lymphocytes, fats etc.

Functions of Lymph:

1. To return fluid and protein from the tissues to the circulation.
2. To transport lymphocytes from lymph gland to circulation.
3. To carry emulsified fat from the intestine to the circulation.
4. Lymphatic glands filter and destroy micro organisms inorder

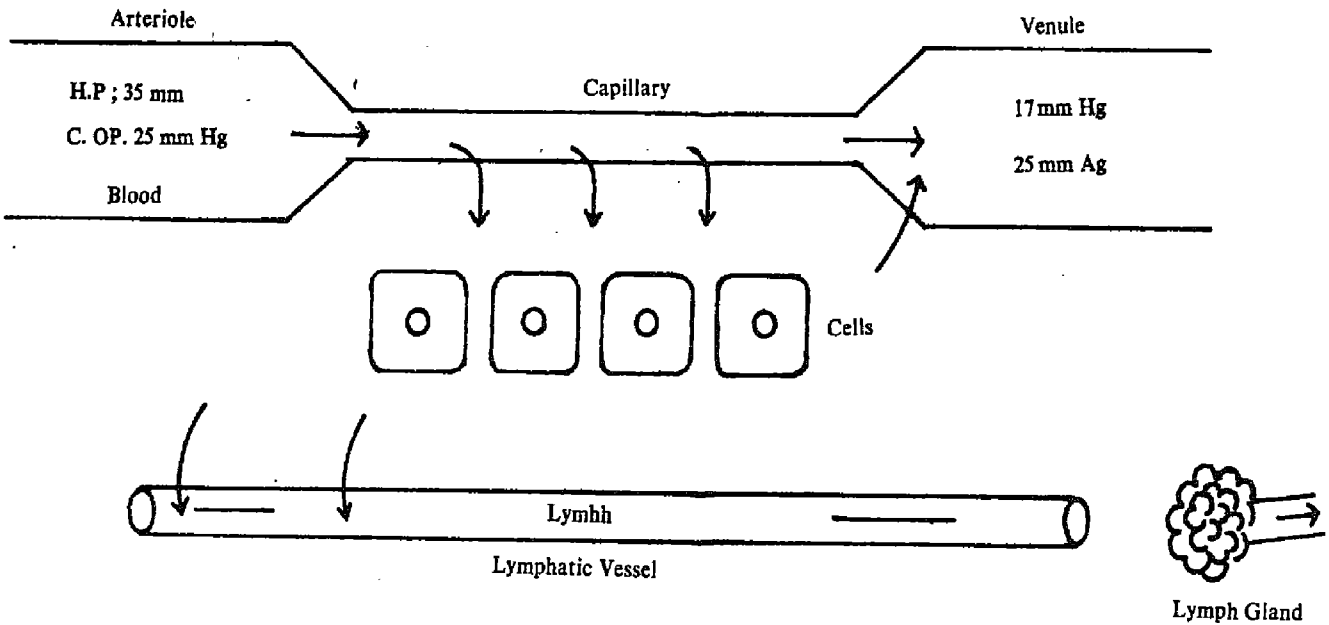


Fig II. 2.3 CIRCULATION OF TISSUE FLUID AND LYMPH

to prevent infection spreading from the point where the organisms entered the tissues to other parts of the body.

5. Following an infection the lymphatic glands produce antibodies to protect the body against subsequent infection.

3.9. Cerebrospinal Fluid (CSF)

The CSF has the same composition as plasma but with less proteins. It is formed in the cavities of cerebral hemispheres. It supplies nutretion to the brain cells. It keeps the brain tissue floating. It protects the brain tissue.

4. Cardio Vascular System

The life of every tissue and organ in the body depends on their receiving an adequate supply of nourishment and O_2 and the removal of waste products which result from their activities. These functions are carried out by the blood, the heart and blood vessels.

Organs of circulatory system consist of the heart, arteries, capillaries and veins.

4.1. The Heart

The heart is divided into right and left halves by means of a septum. Each half consists of two chambers, an upper thin walled atrium and a lower thickwalled ventricle. The atria act as receiving chambers for the pump and the ventricles are distributors.

The opening between the right atrium and right ventricle is guarded by tricuspid valve and the opening between the left atrium and left ventricle is guarded by the mitral valve. These valves permit blood to flow only from atria to ventricles.

4.2. The Blood Vessels Entering and Leaving the Heart

The superior vena cava, inferior vena cava, pulmonary veins enter the heart. The superior vena cava carries impure or deoxygenated blood from the head, neck and upper limbs to the right atrium. The inferior vena cava carries impure or deoxygenated blood from the rest of the body to the right atrium. The pulmonary veins carry oxygenated or pure blood from the lungs to the left atrium.

The blood vessels which leave the heart are the aorta, pulmonary artery. The aorta is the biggest artery in the body which carries oxygenated blood from the left ventricle to the different parts of the body. Pulmonary artery carries impure blood to the lungs for oxygenation.. The aorta and pulmonary artery are also guarded by valves, the aortic and pulmonary valves. Each consists of 3 half-moon shaped cusps hence they are called as semilunar valves.

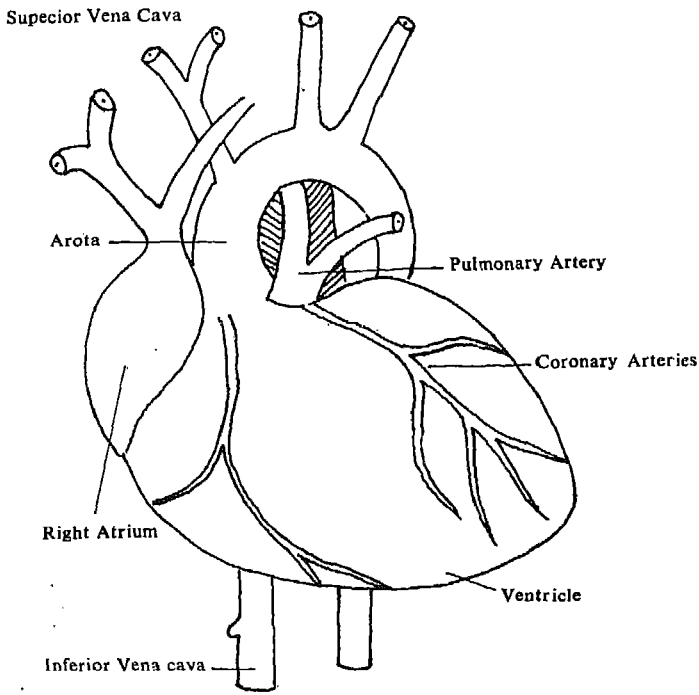


Fig II. 2.4 HEART AND IT'S BLOOD VESSELS

4.3. Junctional Tissues of the Heart

The junctional tissues are highly specialized tissues which start and conduct the cardiac impulse all over the heart. These are:

(1) Sinoatrial node which is the pace maker.
(2) Atrio-ventricular node
(3) Bundle of his.
(4) Right and left bundle branches.
(5) Purkinje fibres.

4.4. Coronary Arteries

The coronary arteries arise from the base of the aorta and supplies the oxygenated blood to the myocardium i.e. the muscles of the heart. If these vessels are narrowed or blocked completely by thrombus, as in coronary thrombosis, the part of the myocardium

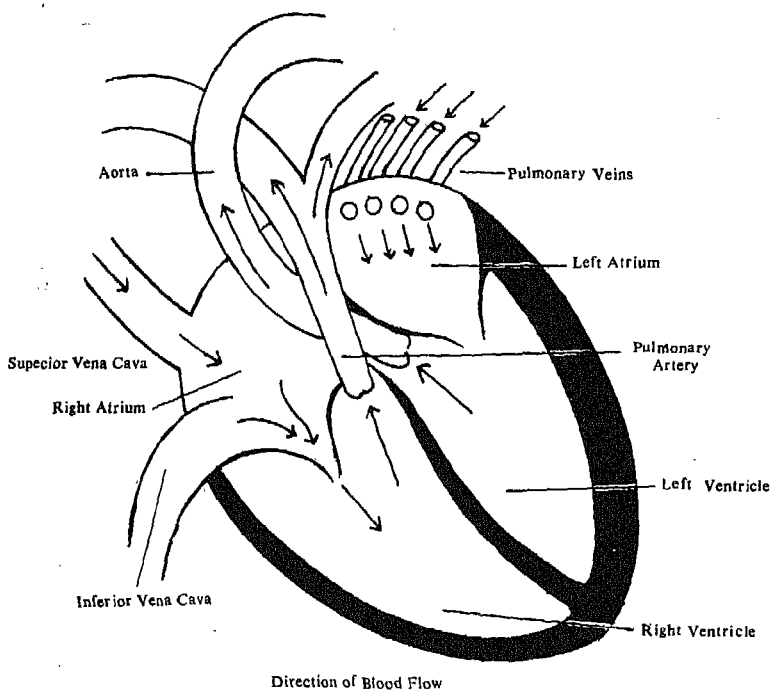


Fig II. 2.5 CIRCULATION THROUGH THE HEART

supplied by the affected branch will be deprived of its blood supply and the muscle will be replaced by a fibrous tissue. If this is extensive it will weaken the pumping power of the heart.

4.5. Pulmonary Circulation

The passage of the venous blood from the right side of the heart through pulmonary artery to the lungs where it becomes oxygenated and its return to the leftatrium via pulmonary vein is called pulmonary circulation.

4.6. Systemic Circulation

The passage of the arterial blood from the left ventricle to the body through the aorta and its branches and its return to right atrium via inferior and superior vena cava is known as systemic circulation.

4.7. The Heart Beat

The function of the heart is to maintain a constant circulation of blood throughout the body by regular rhythnic contraction of the heart muscle. The rate of contraction of heart in a healthy adult male is about 72/min. The heart rate is faster in children, fever, exercise and emotional disturbances.

4.8. Cardiac Cycle

It is the events of a cardiac beat that rhythmically beats from foetal life till death. The various changes that occur during a heart beat undergo cyclic repetition. One complete cycle of such cardiac events of a beat is the cardiac cycle. Each cardiac cycle consists of atrial-systole and atrial diastole, ventricular systole and ventricular diastole. Contruction of the heart is known as systole. Relaxation is known as diastole.

The changes occuring in the heart during cardiac cycle are :

(1) Electrical changes (Electrocardiogram : ECG);
(2) Mechanical changes (Systole and diastole);
(3) Pressure and volume changes;
(4) Heart sounds: There are 2 heart sounds which are audible to the stethoscope. They are described as Luub and Dup.

They occur rhythmically at the beginning of the ventricular systole and ventricular diastole respectively.

I sound: It occurs at the beginning of the ventricular sytole due to the closure of A.V. valves. It is low pitched and of long duration.

II sound: It occurs in the beginning of ventricular diastole due to the closure of semilunar valves. It is sharp shrill and of short-duration.

4.9. Cardiac Output

The heart (i.e. each ventricle) pumps out blood at each beat. The quantity of blood pumped out per minute is called cardiac output. About 70 ml of blood is pumped/beat. This is called stroke volume. Thus in a minute 70x72 = 5040 ml or about 5 litres of blood is pumped by the heart per minute.

4.10. Blood Pressure

Definition: It is the lateral pressure of the blood on the vessel wall i.e. lateral pressure exerted by the coloumn of blood on the

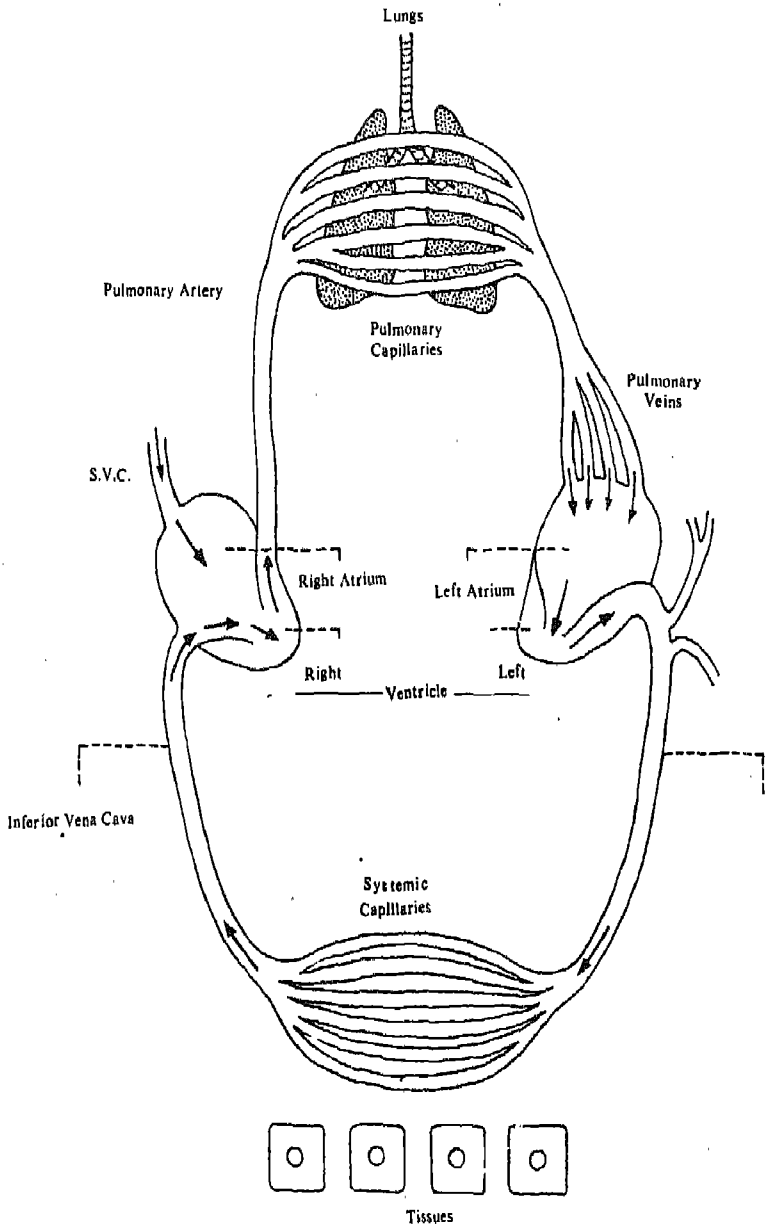


Fig II. 2.6 SYSTEMIC CIRCULATION

arterial wall. These are systolic B.P. and Diastolic B.P. Sytolic BP is the maximum pressure during systole of the heart Diastolic BP is the minimum pressure during the diastole of the heart.

Normal values of BP :

SP : 110-140 mm Hg; average is 120 mm Hg.

DP : 70-90 mm Hg; averate is 80 mm Hg.

4.11. Radial Pulse

During each systole when blood is pumped by left ventricle into the already full aorta there is an increase of pressure in the aorta and expansion of the aorta which is transmitted as a wave to the periphery and is felt on the radial artery as pulse.

4.12. Nerve Supply to the Heart and Blood Vessels

Heart and blood vessels are supplied by parasympathetic and sympathetic nerves which control the heart and lumen of the blood vessels. Lumen of the blood vessel i.e. arteriole can also be altered by certain hormones and drugs. There are certain reflex mechanisms in the body which keep the blood pressure within normal limits. These reflexes depend on the intact parasympathetic & sympathetic neves supplying the heart and blood vessels.

5. Respiratory System

5.1. Main Function

The main functions of respiratory system are the transference of O_2 from the atmosphere to the tissue and CO_2 from tissue to the atmosphere. There are two phases in the interchange of gases.

(1) External respiration: This takes place in the lungs. In this phase O_2 from the atmospheric air is taken up by the blood and CO_2 from the blood is released into the air.

(2) Internal or tissue respiration: In this phase O_2 is transfered from the blood to the tissue and CO_2 is transfered from the tissue to the blood.

5.2. The Air Passages

The organs of respiration consists of air passages and lungs. The air passages conduct air from the atmosphere to the lungs. They are:

nasal cavities
pharynx
larynx
trachea
bronchi
bronchioles.

5.3.The Lungs

The lungs are a pair of conical shaped organs each enveloped in a serous membrane. The right lung has 3 lobes and the left one has 2 lobes. The lungs are situated in thoracic cavity. Each lobe of lungs is made up of a number of small lobules consisting of the alveoli.

The pulmonary artery which arises from the right ventricle supplies the lung. This artery carries impure blood to the lung for purification. The pulmonary veins carry oxygenated blood from the lung to the left auricle.

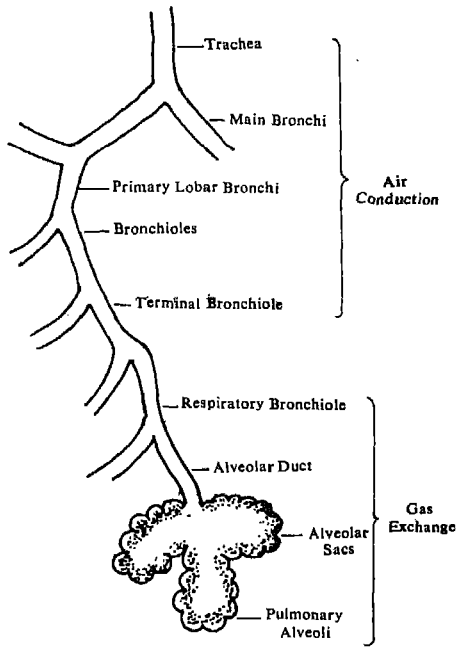


Fig II. 2.7 AIR PASSAGES

5.4. Respiratory Movements

The intake and expulsion of air: The intake of air into the lungs is called inspiration and its expulsion is called expiration. The capacity of the thorax is increased during inspiration by the contraction of the respiratory muscles namely external inter costals and diaphragm, and the intra pleural pressure between the pleurae becomes more negative i.e. —5 mm Hg with respect to atmosphere. The air from the higher pressure i.e. the atmosphere enters the lungs; thus inspiration occurs. This is an active phase.

Expiration is a passive phase during normal quiet breething. At the end of inspiratory phase the external intercostal and diaphragm relax, the thoracic cage returns to original position. Then the volume of the thoracic cage and hence lungs decreases and the air is expelled from the lungs.

5.5. Regulation of Respiration

The normal respiratory rate in adults is 14-18 breaths per min-

ute. It is increased in children and in certain diseases. Respiration is controlled by nervous impulses and by chemical composition of blood.

Besides transfering the respiratory gases from atmosphere to tissue and tissue to atmosphere, the respiratory system is concerned with the production of voice. The voice is produced in the larynx.

5.6. Volume of O_2 and CO_2 Carried by the Blood

The tension of O_2 in the arterial blood is 100 mm Hg. In the tissues the PO_2 is 35 mm Hg. Due to this pressure difference O_2 diffuses into the tissue. When it gives out 5ml of O_2, the PO_2 in the venous blood is 40 mm Hg. O_2 diffuses from the lung to the venous blood due to high PO_2 in the lungs. The PCO_2 in the tissue is greater; so CO_2 diffuses from the tissues to blood. From the blood it is expelled out through the lungs. Arterial blood carries 19.5 ml of O_2 and 48 ml of CO_2 per 100 ml of blood. This reaches the tissues where it gives 5 ml of O_2 to tissues. The O_2 is used by the tissues for the oxidation of food. In turn the tissues produce CO_2 which diffuses into the blood

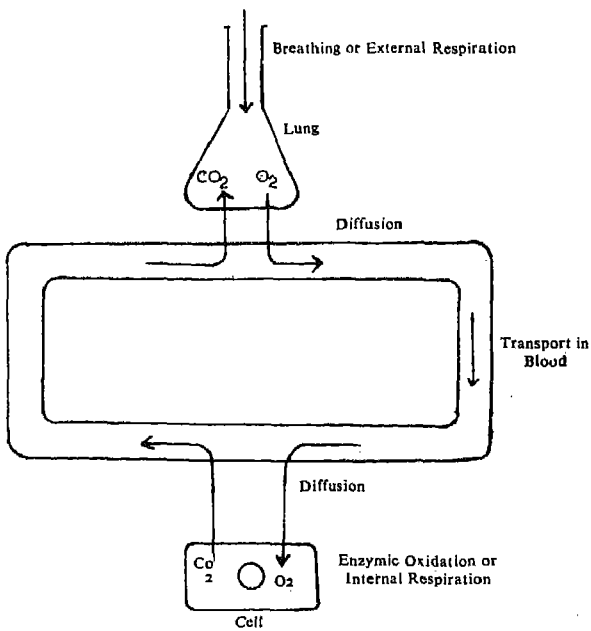


Fig II. 2.8 PROCESS OF RESPIRATION

from the tissues; about 4 ml of CO_2 is taken up by venous blood. The venous blood carries 14.5 ml of O_2 and 52 ml of CO_2 per 100 ml of blood.

5.7. Lung Volumes and Capacities

1. Tidal volume: Volume of air breathed in or out during normal quiet respiration. It is about 500 cc. Much larger amount of air than the normal tidal volume can be inspired or expired.

2. Residual volume: It is the volume of air that remains in the lungs after forcible expiration.

3. Vital capacity: It is the maximum amount of air that can be breathed out after a maximal expiration. It is about 4 litres.

5.8. Hypoxia

Hypoxia is a condition where the cells do not get enough O_2. Lack of O_2 supply to brain for more than 3 minutes leads to damage of the brain, more than 8 minutes leads to death.

5.9. Cyanosis

Cyanosis is a condition in which occurs discoloration of the tips and tongue due to the presence of more than 5 gms of reduced haemoglobin/100 ml of blood. This condition is seen in certain heart diseases.

6. Excretory System

6.1. Organs of Excretion

Kidnays, skin, liver, lungs and digestive tract are the chief organs of excretion. In this chapter you will learn the function of urinary system and skin.

6.2. The Urinary System

The urinary system consists of 2 kidneys, one on either side of the vertebral column. They are situated deep on the posterior wall of upper abdomen. Ureters arise from the kidneys which open into the urinary bladder. Urinary bladder emptys the urine through urethra.

6.3. The Kidney and its Components

The kidney has a rich arterial supply from the renal artery and blood is returned through renal vein. Each kidney consists of 1 million nephrons. Nephron is the structural and functional unit of kidney.

Parts of Nephron:

Glomerulus

Bowman's capsule

Renal tubule: Proximal convoluted tubule
Distal convoluted tubule
Loop of Henle
Collecting duct

6.4. Functions of the Glomerulus

They act as ultra-filters. They filter the blood,. The capsular fluid composition resembles that of plasma except for the plasma proetins. The forces that act at glomerulus to filter the blood is hydrostatic presure 75 mm Hg and osmotic pressure 30 mm Hg. The net filtering force is 45 mm Hg.

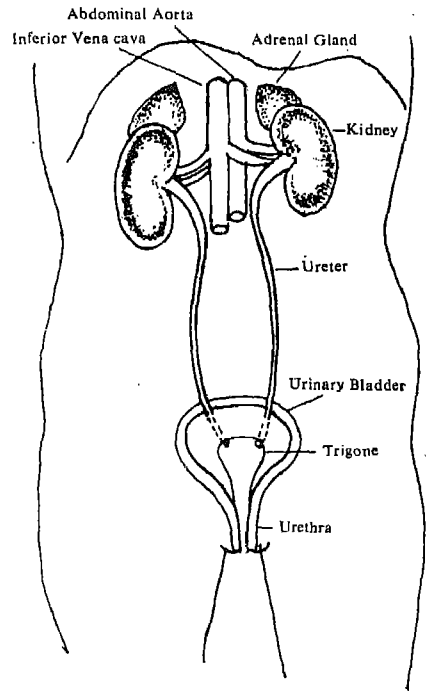


Fig II. 2.9 URINARY SYSTEM

6.5. Functions of the Tubules

Nearly 180 liters of deproteinized plasma is filtered out through glomerulus per day out of which 1½ to 2 litres of urine is formed per day. This shows that about 178 litres are absorbed back in to the blood.

The tubules perform 3 main functions namely:

1. Tubular re-absorption
2. Tubular secretion
3. Synthesis of new substance

6.5.1. Tubular re-absorption: 7/8th of water NaCl is re-absorbed in the PCT. Potassium, glucose are completely reabsorbed in PCT. Biacarbonate & Phosphate are reabsorned in PCT. Uric acid sulphate, Vitamin C, aminoacids, aceto acetic acid etc. are also absorbed in the PCT.

6.5.2. Tubular secretion: Substances like K^+, H^+, Creatinine and

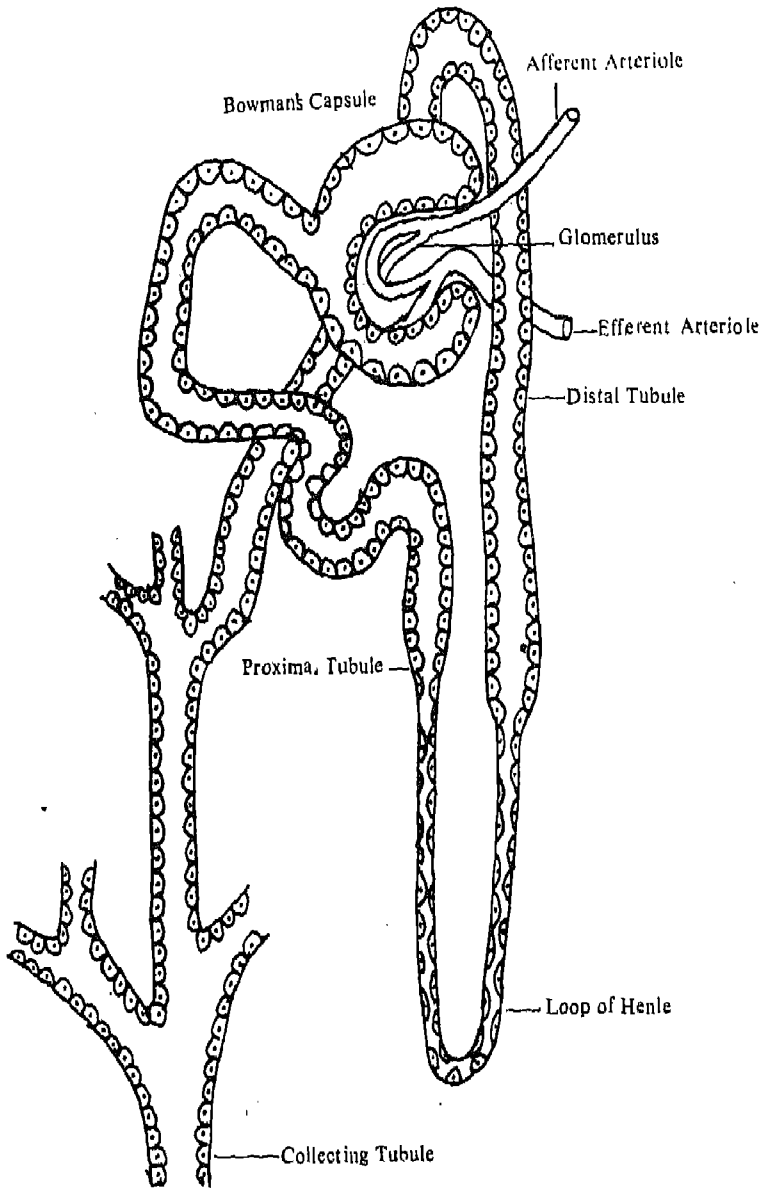


Fig II. 2.10 NEPHRON

drugs like Phenol, Pencillin, Para amino Hippuric acid are secreted into the tubules from the blood.

6.5.3. Synthesis: Ammonia is synthesized and excreted in the urine as Ammonium ion.

6.6. Functions of Kidney

(1) It maintains blood composition by removing unwanted poisonous substances.
(2) It maintains equilbrium of water balance; ionic balance and pH.
(3) It excretes the wate products. They are the nitrogenous and sulphur containing end products of protein metabolism.
(4) It aids to keep up the optimum concentration of important substances.
(5) It excretes poisonous and foreign substances from the body.
(6) Synthesises new substance like NH_3.

Thus the Kidney excretes, sacretes, synthesises and equilibrates to keep up the constancy of the blood, by the processes of filtration, secretion, reabsorption, syntheses. Absorption of several substances in the tubule is controlled by the hormones namely ADH, aldoste rone, parathormone. The urine thus formed is brought to the urinary bladder by the ureters. When the volume reaches to 300 ml it is excreted through the urethra.

6.7. Characteristics of Urine

Colour	: yellow due to urochrome
Odour	: aromatic when fresh; ammonical after bacterial decomposition of urea.
Volume	: 1—1½ lit/24 hrs.
Sp. gr.	: 1001 — 1040
pH	: about 6 (acidic); varies from 4.5 to 8.
Main Constituents	: 1. Water
	2. Inorganic salts: Sodium, Calcium, Potassium, Chloride, Phosphate, Bicarbonate, Sulphate
	3. Organic compounds: Urea

Creatinine
Uric Acid
Ammonia

Abnormal constituents:

(1) Protein (albumin) (occur in disease of nephron)
(2) Blood (occur in disease of nephron)
(3) Glucose (occur in diabetes)
(4) Ketone bodies (in diabetes and starvation)
(5) Bilirubin (jaundice)
(6) Bile salts (jaundice)

7. Skin

The skin forms a covering envelope for the entire surface of the body.

7.1. Structure

There are 2 main layers for the skin. The outer layer is called Epidermis, the inner layer is called Dermis.

The epidermis is divided into several layers:

a. Stratum corneum — horny layer,
b. Stratum Lucidum — transparent layer,
c. Stratum granulosum — granular layer,
d. Stratum Malphigian — prickle celled layer.

Dark pigment melanin is present in the deep layers of epidermis which gives the colour to the skin. The epidermis contains no blood vessels, but lymph circulates.

The dermis consists of the following:

(1) Connective tissue.
(2) Sweat glands — produce sweat & regulate body temperature.
(3) Sebaceous glands — secrete Sebum which helps to keep skin supple and the hair from becoming dry and brittle.
(4) Nerve ending and receptors — are mainly sensory and responsible for general sensation.
(5) Hair follicles are present. The hair arises from these follicles. A tiny muscle Arector pili is attached to the hair follicle. Contraction of this miscle causes the hair to become straight.
(6) Adipose tissue acts as an insulator.
(7) Blood vessels.

7.2. Functions of the Skin

(1) *Protection:* Skin protects the body from external injuries.
(2) *General sensation:* It keeps us in contact with the external

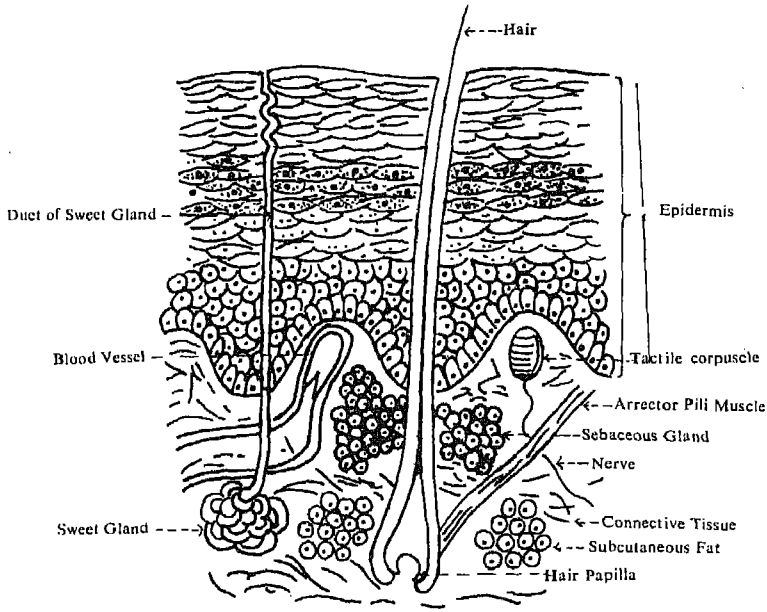


Fig II. 2.11 STRUCTURE OF SKIN

environment by informing us of touch, temperature, pain, pressure, vibration, sensation etc.

(3) *Temperature regulation:* Normal body temperature is 37^0C or 98.6^0F. Temperature is regulated by increasing or decreasing the blood flow and sweat formation by the skin.

(4) *Absorption:* It is capable of absorbing small amounts of oily substances.

(5) *Vitamin D production:* The skin contains dehydrocholesterol. This substance is converted into Vitamin D by the action of sunlight.

8. Digestive System

8.1. The Alimentation

The purpose of digestion is to convert the food stuff by chemical action into simple forms so that they can be absorbed into the blood and utilized by the various tissues of the body. The process of digestion takes place in the alimentary canal and is aided by the accessory organs like salivary glands, liver and pancreas.

Food stuffs are dealt with in the alimentary tract in 5 ways:

1. Mastication or chewing
2. Deglutition or swallowing
3. Digestion
4. Absorption
5. Excretion of waste products.

8.2. Mastication

This function is performed in the mouth by the teeth, tongue and saliva. The food which we eat should have all six components of diet in proper proportion, namely carbohydrates, proteins, fats, vitamins, water & minerals.

The carbohydrates and fats provide energy for the body to perform the bodily function, the proteins are called as body builders. It is required for growth of the tissue.

Vitamins and minerals are required for the proper functioning of different tissues.

Water forms 60% of the body. All chemical reactions take place in water medium.

The food which is taken in the mouth is chewed well to break the food particle into small bits. With the help of saliva it forms a soft bolus which can pass through the oesophagus easily.

8.3. Composition and Functions of Saliva

Saliva is secreted from the 3 types of salivary glands into the mouth. It contains water, inorganic substances and the starch splitting enzyme the ptyalin.

Function:

1) The ptyalin acts on cooked starches and converts them into a sugar called maltose.
2) It moistons the food and acts as a lubricant for swallowing.
3) It helps in speech.
4) It kills the bacteria.

8.4. Swallowing or Deglutition

The act of swallowing takes place in 3 phases.

1) Oral phase—Voluntary
2) Pharyngeal phase —Involuntary
3) Oesophageal phase — Involuntary

1. Oral Phase: During this phase lips are closed. Food is masticated, mixed with saliva and bolus is formed. Bolus passes into the oral pharynx with the he. . of tongue.

2. Pharyngeal Phase: The soft palate shuts off the naso pharynx and the larynx is closed by epiglottis. All these actions prevent the bolus entering the lungs or nares. The bolus is grasped in the pharynx.

3. Oesophaseal Phase: The bolus is carried down the oesophagus by the contraction of muscles of oesophageal wall to the stomach.

8.5. Functions of Stomach

1) It acts as reservoir for food.
2) It secretes gastric juice containing
   a) HCl which acidifies the food;
      aids the action of pepsin;
      anti bacterial;
   b) Pepsin, a proteolytic enzyme which converts proteins into peptones.
3) It secretes the intrinsic factor essential for the absorption of the vit B_{12} which is required for the maturation of R.B.C.
4) Water, glucose, alcohol and some drugs are absorbed
5) It breaks down food into chyme (partially digested semi liquid food).
   Small quantities of chyme is pourced into the duodenum intermittently.

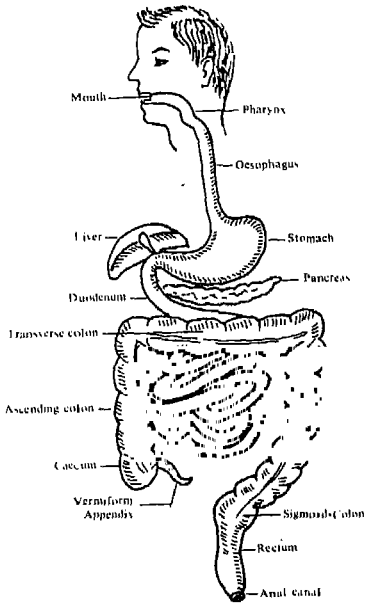


Fig II. 2.12. DIGESTIVE SYSTEM

8.6. Digestion in the Small Intestine

8.6.1. Digestive glands and their secretions: Liver produces bile. It is concentrated and stored in the gall bladder. When food enters the duodenum, the gall bladder pours bile into the duodenum through the bile duct. The pancreas brings pancreatic juice through the pancreatic duct, which joins the bile duct and finally opens into the duodenum.

Small intestine has a number of glands which secret the intestinal juice or succus entericus. This is an alkaline fluid. Bile contains bile pigments and bile salts.

Pencreatic juice contains bicarbonate, the proteolytic enzymes trypsin, chymotrypsin and the fat splitting ehzyme pancreatic lipase.

Succus entericus consists of the following enzymes:

Erepsin: which converts peptides into amino-cids;

Invertase: converts can sugar into glucose;

Maltose: converts maltose into glucose;

Enterokinase: converts the trypsinogen to trypsin.

8.6.2. Digestion of carbohydrates:

Types of Carbohydrates	
Glucose, dextrose or grape sugar Fructose Galactose	monosaccharide
Surcrose or cane sugar Maltose or malt sugar Lactose or milk sugar	disaccharides
Starches Cellulose Glycogen	polysaccharides

The Monosaccharide is the simplest form of the carbohydrate found in the body.

Starches and sugars are converted into glucose as follows.

a) Cooked starch $\xrightarrow[\text{Saliva}]{\text{Ptylin}}$ Maltose

b) All starches $\xrightarrow[\text{Pancreatic juice}]{\text{Amylase}}$ Maltose

c) Maltose $\xrightarrow[\text{Intestinal juice}]{\text{Maltase}}$ Glucose

d) Cane sugar $\xrightarrow[\text{Intestinal juice}]{\text{Invertase}}$ Glucose & Fructose

The starch which is taken in the food is converted to glucose which can be absorbed in the stomach and intestine and finally into the blood.

8.6.3. Fat digestion:

Fats $\xrightarrow[\text{Pancreatic juice}]{\text{Lipase}}$ fatty acids and glycerol

The bile salts are essential for the digestion and absorption of fat into the villi of the small intestine.

8.6.4. Protein digestion: The proteins are complex organic compounds containing nitrogen, sulphur and phosphorus in additon to carbon, hydrogen and oxygen.

1) Proteins $\xrightarrow[\text{HCL}]{\text{Pepsin}}$ Proteoses and peptones (within the stomach)

2) Peptones $\xrightarrow[\text{Erepsin (succus entricus)}]{\text{Trypsin (pancreatic juice)}}$ amino acids (in the intestine)

3) Amino acids are absorbed in the villi of small intestine, and conveyed to the liver by the blood. These amino acids are used for the repair and growth of the tissues.

Nitrogen containing portion of the amino acids are not required by the tissue hence it is removed by the liver and excreted in the urine as urea.

8.7. Functions of Large Intestine

It secretes mucous which lubricates the faeces and facilitates their passage through the rectum and anus.

Absorption: The contents of the small intestine are in liquid state. The large intestine absorbs water, salts, some glucose thus making the contents almost solid.

Excretion: Undigested materials like cellulose of vegetable, unabsorbed calcium, iron, drugs etc. are excreted in the faeces.

Defecation: The faeces accumulates in the rectum, the sphincter muscle of the anus relaxes, the muscular walls of the rectum contract, the pressure within the abdomen is raised, the bowels are evacuated.

8.8. Liver

Functions of the liver:

1. Secretion of bile: The bile is formed from the liver cells; it contains bile salts, bile pigments, water, mucin, and cholesterol.
   The bile salts activate pancreatic lipase, and aid in the digestion and absorption of fats from the intestine.
2. Storage of glycogen: The glucose which is absorbed in the small intestine is carried to the liver. Here it is converted to glycogen and stored. When ever it is required it is converted to glucose and utilized by the tissues of the body.
3. Formation of urea: Nitrogen containing portion of the amino acids is removed and converted into urea which in turn is carried to the kidney for excretion in the urine. This process is called deamination of the aminoacids.
4. Production of plasma proteins: The plasma proteins and some coagulation factors which are also proteins are synthesized in the liver.
5. Storage of vit B_{12} and Iron.

8.9. Pancreas

The pancreas has 2 types of secretion.

1. Exocrine function: Pancreatic juice is produced in the pancreatic acini and poured into the duodenum through the pancreatic duct.
2. Endocrine function: The Islets of Langerhans produce two hormones namely insulin and glucagon which are directly poured into the blood.

Pancreatic juice is an important digestive juice. It contains high concentration of:

(1) Bicarbonate which neutralizes the acid food coming from the stomach to the duodenum. The alkaline pH facilitates the action of pancreatic enzyme.
(2) Amylase, an enzyme which converts starch to maltose.
(3) Lipase, a fat splitting enzymes which converts fats into fatty acids and glycerol.
(4) Trypsin and chymotrypsin: These are proteolytic enzymes, which convert protein and polypeptides of amino acids.

8.10. Gall Bladder

It is a small pear-shaped sac situated on the under surface of the right lobe of the liver. Its duct is called as cystic duct which unites with hepatic duct from the liver to form common bile duct. The bile is produced by the liver cells and stored in the gall bladder. Gall bladder not only stores the bile but also concentrates the bile by absorbing water. Bile remains in the gall bladder until it is required for purpose of digestion. After a fat meal containing fat, the gall bladder contracts and discharges the bile via the cystic duct and bile duct into the duodenum.

8.11. Intestinal Movements

Small intestine shows three important types of movements:

(1) Segmenting movements helps in the mixing up of partially digested food with the digestive juices.
(2) Peristaltic movement occurs in the oro-anal direction. By this movement the digested food is slowly driven into the large intertine.
(3) Pendular movement helps in the mixing up of food and digestive juice.

9. Endocrine Glands

9.1 Endocrinology

Endocrinology is the study of various products secreted by certain glands know as *"Endocrine glands"* or "Ductless glands". These are known as endocrine glands because their secretions are poured into blood directly without the help of any ducts. The secretions of these glands are known as *Hormones.*

The following are the endocrine glands:

1) Pituitary
2) Thyroid
3) Adrenal
4) Pancreas
5) Parathyroid
6) Ovary (in the Female only)
7) Testes (in the Male only)

9.2. Pituitary

Pituitary is situated in the central nervous system at the base of the brain. The Pituitary gland is divided into two parts, Anterior pituitary and Posterior pituitary. The important hormones and their actions are given in the chart on page 41.

9.3. Thyroid Gland

Thyroid gland is made up of 2 lobes: right lobe and left lobe. They are situated on the sides of upper part of trachea. Right lobe and left lobe are connected by Thyroid Isthmus.

The hormone secreted by Thyroid gland is known as *Thyroxine.*

Major functions of Thyroxine:

1) Stimulates oxygen consumption by the body and produces a lot of heat.
2) It is necessary for normal growth of the body.
3) It is necessary for normal growth and maturation of the nervous system of the child.

Nervous System of the child.

The thyroid gland also secretes another hormone known as Calcitonin which decreases blood Calcium level.

9.4. Parathyroid

There are 4 small glands, two on each side of the thyroid gland in the neck. The hormone secreted by this gland is "Parathormone". Parathormone increases Ca^{++} absorption from bones and kidneys. Its main action is to increase blood calcium level. Normal value of plasma calcium is 8.5 to 10.5 mg/100 ml.

9.5. Adrenal

There are two adrenal glands. They are attached to the superior pole of each kidney. They are divided into 2 parts: Adrenal Cortex and Adrenal Medulla.

The hormones secreted from cortex are known as *corticosteroids* and that from medulla are known as medullary hormones. There are two important hormones secreted from Adrenal Cortex: (1) Aldosterone and (2) Cortisol (Glucocorticoides).

Aldosterone: Helps in the regulation of Sodium and Potassium content of body by kidneys.

Cortisol: Helps in Carbohydrate metabolism. Since it acts on glucose of the body it comes under the group of substances called Glucocorticoides.

There are 2 important hormones produced by Adrenal Medulla. They are (1) Adrenaline and (2) Non-adrenalin.

Actions of adrenaline: Adrenaline increases heart rate and force of contraction of heart. It constricts most of the blood vessels and dilates the Coronary blood vessels and blood vessels supplying the skeletal muscle.

Actions of Non-adrenaline: It causes constriction of all the blood vessels which in turn increases the Blood pressure.

9.6. Pancreas

The hormone secreted by Pancreas is *Insulin*. Insulin is secreted by B-cells of Islets of Longerhans of pancreas. The major action of insulin is to reduce blood glucose level. (Normal value is 80-120 mg/100 ml). Insulin increases glucose usage by most tissues.

If the insulin secretion is reduced a disease known as "Diabetes

mellitus" occurs. In this disease there is an increase in blood glucose level. When Plasma level of glucose increases to 180 mg or more/ 100 ml, the glucose starts appearing in the urine.

10. Reproductive System

10.1. Ovaries and Their Functions

The ovaries are two almond-shaped glands placed one on each side of the uterus below the uterine tubes. These are primary sex organs of female. They contain a large number of immature ova called 'primodial germ cells'. One of these cells grows and matures to form graffian follicle which contains ovum surrounded by the granulosum cells. On 14th day of 28 day menstrual cycle the ovum is liberated. This is known as ovulation. After the ovum is shed the graffian follicle is filled with lutein cells known as corpus luteum.

Functions of ovary:

1) Production of ova,
2) The graffian follicle secretes the hormone estrogen,
3) Corpus luteum secretes the hormones progesterone and estrosen.

10.1.1. Functions of estrogen: Its actions are principally on pituitary, the brain, breasts and the female reproductive organs.

1) Facilitates the growth of the ovarian follicles.
2) Brings about cyclical changes in the endometrium, cervix and vagina.
3) Increases the muscular content of uterus.
4) Produces duct growth in the breast.
5) Brings about bodily changes at puberty.
6) Responsible for secondary sexual characters i.e. high pitched voice, less body hair, more scalp hair, growth of axillary hair. etc.
7) Lowers the plasma cholesterol level.
8) Brings about physical and mental qualities which distinguish the normal woman.

10.1.2. Actions of progesterone:

1) Responsible for progestational changes in the endometrium and the cyclical changes in the cervix and vagina.
2) It decreases the excitability of the uterine muscles.

3) It stimulates the development of alveoli and lobules in breast.
4) Prevents ovulation.
5) It increases metabolic rate.
6) Brings about inplantation of fertilized ovum.

All these ovarian functions are controlled by the hormones secreted by the anterior pituitary i.e. F.S.H. and LH.

10.2. Testes and Their Functions

Testis is the primary sex organ of male. It has two functions.

1) Spermatogenesis: i.e . the production of spermatozoa.
2) Secretion of male sex hormone—Testosterone by the leydig cells or interstitial cells.

10.2.1. Spermatogenesis: Spermatozoa are produced in the seminiferous tobules. Several factors control the spermatogenesis. They are the 1) Pituitary hormone F.S.H., 2) Testosterone, 3) LH through Testosterone, 4) Temperature.

Composition of semen:

Colour : White
Sp. gravity : 1026
pH : 7.35-7.5
Sperm : 100 million/ml

Other components:
Fructose
Ascorbic acid
} from the seminal vesicles (60%)

Spermine
Citric acid
Cholesterol phosphatepice
Fibrinolysis, fibrinogemese
} from prostate 20%

Phosphate
Bicarbonate
Hyal uronidese
} Buffers

10.2.2. Actions of Testosterone:

1) Develops and maintains the male secondary sex characterstics namely growth of external genitalia; accessory sex organs like seminal vesciles, prostrate and Cowper's gland; change in voice; appearance of beard; hair in axilla; on chest; increase in body hair; mental changes; body configuration; increase in secretion of sebaceous glands.
2) Exert an important protein anabolic action.
3) Promotes muscular growth.

10.3. Vasectomy

It is a simple procedure for sterilization in the male, involving Ligation of and section of vas deferens which carries sperms. So sperm are not present in semen; other secretions are present. The function of leydig cell is unaffected. Secondary sex organs remain normal

10.4. Tubectomy

This is surgical procedure performed in female. The fellopian tubes conduct the ovum from the ovary to the uterus. These tubes are cut and ligated to prevent fertilization of ovum.

11. References

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